N89-15009

LOW-GRAVITY IMPACT EXPERIMENTS: PROGRESS TOWARD A FACILITY DEFINITION

Mark J. Cintala, Code SN12, NASA Johnson Space Center, Houston, TX 77058

Innumerable efforts have been made to understand the cratering process and its ramifications in terms of planetary observations, during which the role of gravity has often come into question. Well-known facilities and experiments both have been devoted in many cases to unraveling the contribution of gravitational acceleration to cratering mechanisms. Included among these are the explosion experiments in low-gravity aircraft performed by Johnson et al.(1), the drop-platform experiments of Gault and Wedekind(2), and the high-g centrifuge experiments of Holsapple and Schmidt.(3,4) Considerable insight into the effects of gravity, among other factors, has been gained through studies exemplified by those cited above. Even so, other avenues of investigation have been out of reach to workers confined to the terrestrial laboratory. It is in this light that the Space Station is being examined as a vehicle with the potential to support unique and otherwise impractical impact experiments. This report summarizes the results of studies performed by members of the planetary cratering community; their names and affiliations are listed below.

Scientific Rationale and Experiment Types -- The microgravity environment is useful in two basic ways. First, with some coaxing, it can permit direct experimentation at the gravity levels characteristic of the vast majority of planetary objects in the Solar System. Second, virtual weightlessness is a factor that enables the execution of experiments that are inordinately difficult or practically impossible to accomplish in a constant 1-g environment. Thus, there are three basic types of impact experiments that could be performed in a Space Station-supported laboratory: direct simulation (of asteroidal regoliths, for instance), process studies (e.g., collisional disruption of weakly bound, free-floating objects), and examination of scaling relationships (the control of crater size and geometry, for example, by forces that are safely negligible in higher gravity fields, such as electrostatic attraction). It must be kept in mind that the overwhelming majority of experimental data have been collected at 1-g. Empirical estimates of ejecta-deposit thicknesses, for instance, rely primarily on terrestrial impact- and explosion-cratering data.(5,6,7) On the other hand, theoretical predictions exist (8,9), but they remain to be tested at different gravity levels.

The Space Station Impact Facility -- The design of an impact facility for the Space Station is being pursued within the framework of the desired capabilities and goals of experimentation that would be performed with it. Among the requirements imposed by the group are

- High impact velocities (at least 6 km/s)
- As large an impact chamber as possible (to accommodate, for instance, the large craters that would be formed at low gravity levels)
- A variety of data-gathering methods (film, video, oscillograph, digital)
- Maximum flexibility in accommodating targets of different types (ranging from massive containers of noncohesive material to solid, free-floating objects)
- Peak electrical power capability of ~25 kW (necessary for short periods of time for chamber lighting and high-speed camera operation)
- Ability to support acceleration levels over the range of 0-0.2g.

Discussion -- These were levied with minimal restriction of the definition process to detailed Space Station capabilities as currently envisioned. Thus, it is a virtual certainty that actual vehicle performance will result in some rethinking of these and other requirements. In this vein, the Initial Operational Capability (IOC) version of the Space Station will be considerably more spartan in its ability to support the sort of facility described above. Nevertheless, a variety of very interesting experiments could still be performed; in particular, those not requiring variable gravity levels would be well-suited to the IOC facility. Not only would they provide new scientific data, but they would also serve to establish experimental procedures in the Space-Station environment. This experience would then provide a valuable foundation for operations with the expanded facility on the post-IOC Station.

At this early stage in the definition of the facility, the type of projectile accelerator is uncertain; rapid advances in railgun and other related technologies portend a precarious future for light-gas guns, especially in terms of the potential for high velocities exhibited by the former. (Should the electromagnetic accelerators be incorporated, their penchant toward high-velocities might permit their use in meteor studies, in which projectiles of various physical properties would be launched into the atmosphere. The resulting artificial meteors would then be examined simultaneously from below and above.)

The requirements of a large target chamber and variable gravity are somewhat uncompromising in an engineering sense. It is likely that centrifugal force would be employed to yield the desired accelerations in the post-IOC version, but the large volume required essentially eliminates simple centrifuges as candidate mechanisms. It is suggested instead that a detachable module or modular array be included as part of the post-IOC the Space Station, carrying its own guidance and propulsion capability. It would then separate from the Station to a safe distance and "spin up" to generate the desired g-level. Numerous experiments needing variable accelerations would benefit from this capability.

A number of technical areas have been identified which could provoke some difficulties unless studies are undertaken to determine remedial solutions or procedures. Target preparation and handling, for instance, especially in the case of fragmental or liquid materials, will pose some challenges; not only would it be a more difficult matter to fabricate a target of sand or some other fragmental material in low to zero gravity, but the floating silicates would pose a nontrivial health hazard. The absolute size of the target chamber is still somewhat in question, since theoretical predictions and extrapolations of experimental data are the only sources of information on crater size at the low g-levels that would be employed. The issue is complicated somewhat by the likelihood that stress waves reflected from the walls of the target containers could be relatively more severe than their generally ignorable counterparts in the terrestrial laboratory.

Many of these technical challenges could be approached through judicious experimentation on the NASA KC-135 Reduced Gravity Aircraft and/or the large NASA drop towers. These facilities can provide support over a wide range of experiment conditions and gravity levels, permitting engineering, procedural, and, most significantly, scientific questions to be addressed in some detail. With the benefit of such experiences, planning for the Space Station facility could be carried out with substantially more confidence.

References -- (1)S.W. Johnson *et al.* (1969) *JGR* *74*, 4838. (2)D.E. Gault and J.A. Wedekind (1977) *Impact Explos. Cratering*, D.J. Roddy, R.O. Pepin, and R.B. Merrill, eds., (New York), 1231. (3)R.M. Schmidt (1977) *Impact Explos. Cratering*, D.J. Roddy, R.O. Pepin, and R.B. Merrill, eds., (New York), 1261. (4)R.M. Schmidt and K. A. Holsapple (1980) *JGR* *85*, 235. (5)T.R. McGetchin *et al.* (1973) *EPSL* *20*, 226; M. Settle *et al.* (1974) *EPSL* *23*, 271. (6)R.J. Pike (1974) *EPSL* *23*, 265. (7)D. Stöffler *et al.* (1975) *JGR* *80*, 4062.

Microgravity Impact Working Group

T.J. Ahrens (Cal. Inst. of Tech.)
M.J. Cintala* (NASA JSC)
S.E. Dwornik (Ball Aerospace)
D.E. Gault (Murphys Center for Planetology)
R. Greeley (ASU)
R.A.F. Grieve (Bur. of Energy, Mines, and Resources, Canada)
B.R. Hawke (Univ. of Hawaii)
F. Hörz (NASA JSC)
D.L. Orphal (Cal. Research and Technology)
D. Roalstad (Ball Aerospace)
D.J. Roddy (USGS, Flagstaff)
R.M. Schmidt (Boeing Aerospace)
P.H. Schultz (Brown Univ.)

* Chairman